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RESEARCH PAPER

Organic matter accumulation in hill forests of Chittagong region, Bangladesh

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Abstract: Litter fall and its effect on forest soil properties at each decomposition stages were investigated in tropical monsoon climatic conditions of three plantations (7-year acacia plantation, 15-year acacia plantation and 18-year mixed plantation) and one natural forest (Sitapahar forest) from Chittagong hilly region of Bangladesh. Results showed that total accumulation of organic matter increased with plantation age, accompanying with a decrease of annual accumulation rate. Within the same vegetation type, the organic accumulation of both fresh and partially decomposed litter with humus varied significantly ($p \leq 0.05$) on hill positions, being highest on bottom slope and decreased gradually towards hilltop in the forest. Reverse trend in accumulation of soil organic matters was shown in 15-year *Acacia auriculiformis* plantation, from where fuel wood collected. In 7- and 15-year acacia and 18-year mixed broadleaved plantations, rates of total organic matter production consisting of fresh, partially and completely decomposed litter as well as incorporated organic matter in soil were 2554.31, 705.79 and 1028.01 $kg \cdot ha^{-1} \cdot a^{-1}$, respectively, and the corresponding contribution from fresh litter were 38.23, 19.40 and 30.48 $kg \cdot ha^{-1} \cdot a^{-1}$, respectively. In the three plantations and the natural forest, on an average fresh litter constituted 32.45%, partially decomposed litter with humus 13.50% and incorporated organic matter in soil 54.56% of the total organic matter production with mean litter thickness of 0.90 cm. Soil acidity increased with the increase of decomposition stage of organic matter.

Keywords: accumulation rate; decomposition stages; hill forest; organic matter; plantation forest

Introduction

Litter occupies a unique position in the nutrient cycle of forest ecosystem. As a source of plant nutrients, litter decomposition by soil microbes affects physiochemical properties of soil (Auchmoody 1972; Hassan and Islam 1984; Pandey and Singh 1984). The decomposition process has the significance in the maintenance of forest productivity and nutrient releases in available form for reuse by plants (Schlesinger 1997; Jha et al. 1999). Total litter in forest ecosystem depends on the total of forest resource. However, since 1960, Bangladesh forest resource has reduced largely due to increasing deforestation of natural forests in the hilly region and in other parts through illicit felling, fuel wood collection, and grazing and settlement in forest areas by rapidly growing population. Therefore, plantations were raised with fuel, timber and industrial wood species to meet wood demand of the country and to respond the slogan of environmental conservation with the financial assistance of international organization. Chittagong University, located at hilly terrain, has afforested fast growing exotic and indigenous species in the 1980s replacing secondary vegetation such as thickets with a few scattered trees, thatching grasses and bamboo and now most of the areas are growing artificial forest. Afforestation of plantation in Bangladesh is benefited to the conservation of soil and biodiversity, creation of recreational potentiality, protection of ground water reserves and from natural calamities, like 'Sidr'. Several studies have been done on the performance of planted species in Chittagong University campus alone (Osman et al. 1992a, 1992b; Haque et al. 1992). One of the most obvious effects of afforestation is the accumulation of litter on soil surface. Osman et al. (1995) observed that plantations of *Acacia auriculiformis, Acacia mangium, Eucalyptus camaldulensis* and *Pinus caribaea,* increased organic matter, total nitrogen, available P and pH of soil in Keochia Silvicultural Research Station in Chittagong. Similar studies are also available in other parts of Bangladesh. For instance, Miah et al. (2001) estimated the carbon stock of 20.04 t within 30 cm soil depth, 56.21 t in humus with negligible depth and 0.77 t in 1−3 cm soil depth per hectare in a 3-year mixed plantation in Chittagong region of Bangladesh.

Litter decomposition and nutrient release in forest ecosystems have received wide attention in the world. In other countries, many finer level researches on litter decomposition and nutrient release have been done using litter bag technique. Moreover, Zheng et al. (2006) worked on decomposition of litter and its constituent materials such as leaf litter, flower, coarse and thin

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wood and nutrient release in tropical seasonal rain forest of Southwest China. Fonte and Schowatter (2004) examined litter quality and decomposition rate of green leaves compared to senescent litter fall for dominant tree species in tropical ecosystem of Puerto Rico, USA using litter bag technique. In the last few decades, Kyoto Protocol has been recognized sequestration of carbon as an important environmental effect of afforestation. Many studies (e.g. Post and Kown 2000; Monson et al. 2002; Terakunpisut et al. 2007) have also been done on carbon sequestration by forest vegetation in relation to global warming in different parts of the world.

The present study was undertaken in three different aged plantations of 7 to 18 years within hills of Chittagong University campus and in a natural forest on hills at Kaptai, 70 km away outside the campus, to determine the rates of organic matter accumulation at different decomposition stages and the effects of forests on soil physicochemical properties. Hypotheses of this study were that (1) plantations or natural forests definitely would influence the soil properties and the effect of natural forest on changes in the soil properties would be larger than that of plantations, (2) accumulation of organic matter in the same aged plantation would be similar at all the hill positions, and increase with increasing age of the plantation, and (3) accumulation rates of organic matter at different decomposition stages would be higher in a plantation than in an old natural forest.

Materials and methods

Following four categories of forests were selected in the tropical monsoon climate characterized by hot humid summer receiving about 90% rainfall of the year from May to October and dry season extending from November to next April, with mean annual rainfall of 287 cm and mean annual temperature of 26°C.

(1) 18-year mixed plantation: This site was in 18-year-old mixed undisturbed plantation situated on the southern aspect of the hill near Vice Chancellor's Banglow in Chittagong University campus. Species composition of the forest was mainly of Dhakijam (*Syzyzium grande*), Bhadi (*Lannea grandis*), Chatim (*Alstonia scholaris*), Bohera (*Terminalia belerica*) and Jarul (*Lagerstroemia speciosa*) with 1.5 m height dense undergrowth. The undergrowth consisted of Bhat (*Clerodendrum viscosum*), Tokma (*Hyptic suaveolens*), Assamlata (*Eupatorium odoratum*), and Taralata (*Mikania cordata*). In this plantation, litter thickness was uniform on the top hill and variable in middle and bottom hill positions. Litter thickness at the top, middle and bottom were 0.49 cm, 0.91 cm and 0.93 cm, respectively.

(2) 15-year acacia plantation: This site was in 15-year-old disturbed *Acacia auriculiformis* plantation situated on the western aspect of the hill near Amanath hall in Chittagong University campus. Litter collection in the forest was the most frequent as compared with all other forests of the area because of easy approach through the main road by the poor people. This plantation contained a few undergrowth of vine with an average height of 0.85 m. In this plantation, litter thickness was thin and almost similar being 0.21 cm on top, 0.20 cm on middle and 0.16 cm on bottom hill position.

(3) 7-year acacia plantation: This site was in 7-year-old well-established, undisturbed *Acacia auriculiformis* plantation on the eastern aspect of the hill in the south campus of Chittagong University and possessed dense undergrowth with the height of 1.5 m, consisted of Bhat (*Clerodendron infortanatum*), Assamlata (*Eupatorium odoratum*) and vines. In this plantation, litter thickness was uniform on each hill position and variable in top, middle and bottom hill positions. Litter thickness at the top, middle and bottom were 0.66 cm, 1.30 cm and 0.86 cm, respectively. Soil texture in the plantations described above varied from sandy loam to sandy clay loam, derived from tertiary hill sediments of Dupitila and Tipam formations (SRDI, 1974).

(4) Sitapahar natural forest at Kaptai: This site was in a natural forest reserve situated on eastern aspect of the hill at Sitapahar, Kaptai in Chittagong Hill Tracts. This natural forest is rich in plant species, mainly of Urium (*Mangifera sylvatica*), Chundal (*Swintonia helferi*), Hijuli (*Ficus ramphii*), Barta (*Artocarpus lacucha*), Assatya (*Ficus religiosa*), Lotkan (*Baccaurea ramiflora*), Sindur (*Aantidesma lucidum*), Chalta (*Dillenia indica*), Batna (*Quercus* spp), Simul (*Bombax ceiba*), Chatian (*Alstonia scholaris*)), Civit (*Swintonia florebundo*), Shelbadi (*Garuga pinata*), Changi (*Phoibe paniculata*), Udal (*Sterculia colorata*), Kao (*Olea dioica*), etc. Undergrowth with mean height of about 2 m consisted of Assamlata (*Eupatorium odoratum*), Bhat (*Clerodendrum viscosum*), Muli bamboo (*Melocanna baccifera*) and different vines. Land of Sitapahar forest reserve originates from the Pliocene and Miocene tertiary period and is composed of upped Bhuban and Bokabil formations. Lithologically, the formation of upper Bhuban is characterized by thick shale with thick sandy horizon in the base and the formation of Bokabil by thick shale of fine to medium grained sandy horizon in the middle part. Soils of the hills were sands or sandy loam. In the natural forest, litter thickness was almost uniform over the whole forest. Litter thickness at top, middle and bottom were 2.23 cm, 1.72 cm and 2.07 cm, respectively.

Litter and soil sampling

Litter and soil samples were collected from each of the four sites. Fallen litter classified as fresh was collected separately from partially decomposed litter with humus, which collected together. Three sampling plots with the size of 0.5 m × 0.5 m, were selected on top, middle and bottom slope of the hill at each site. Triplicate samples were collected from each slope. Thicknesses and weight of fresh litter and of partially decomposed litter with humus were measured using centimeter scale and balance, respectively. Bulk density samples were collected from the soil depths of 0–4 cm and 4–8 cm using cores.

Soil analysis and calculation

Soil organic matter was determined by wet oxidation method and soil pH (1:2, soil-water ratio) by TOA pH meter. Field moist soil cores were allowed to dry in an oven at 105°C for 8 h and re-weighed to determine moisture content and dry bulk density. Soil organic matter pool was calculated from percentages of

organic matter and bulk density values for two different soil depths of 0–4 cm and 4–8 cm. Total organic matter production was the sum of organic matter at different decomposition stages and incorporated organic matter in soil. Annual rate of litter decomposition for each of the plantations was calculated by dividing the age of the plantation. Duncan Multiple Range Test was done for data of each of the parameters using SPSS package to determine levels of significance for the means of each hill position.

Results and discussion

Moisture content and bulk density

Moisture contents in each of the plantations including natural forest varied in a narrow range at both the depths of 0–4 cm and 4–8 cm, and in some cases in the plantations, the value showed significant ($p \leq 0.05$) decrease from top towards bottom hill position (Table 1). In the acacia plantations, moisture content at 0–4 cm soil depth varied from the lowest 15.48% on middle hill position in 7-year plantation to the highest 20.67% on top hill position in 15-year plantation. A similar inconsistent result for moisture content was also reported by Haque (1997) in different pine plantations in Scotland, U.K. Bulk density showed no definite trend among three different hill positions within each vegetation type and the values were higher in 4–8 cm soil depth compared to surface soil (0–4 cm) containing more organic matter (Table 1).

Soil pH

In all the four forest types, soil pH on all the hill positions was higher at 0–4 cm depth than at 4–8 cm depth, and showed no general trend for hill positions. This finding suggested that litter decomposition reduced soil pH and increased acidity to the immediate lower layer through leaching from upper layer. This reduction was more in the natural forest than that in plantations. Comparison within the plantations, 18-year mixed plantation showed more lowering soil pH than younger plantations (Table 1). Soil pH in the four forest types at 0–4 cm depth varied from 4.50 on middle position in 15-year acacia plantation to 5.60 on hill top position in natural forest, while at 4–8 cm depth varied from 4.40 on bottom slope in the same aged plantation to 4.88 on hilltop in the natural forest.

Table 1. Soil physicochemical properties at two soil depths on three hill positions in four forest types of Chittagong region in Bangladesh

Forest type	Soil depth (cm)	Moisture (%)			Bulk density (g/cc)			pH			Organic matter (%)		
		Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom
18-year mixed plantation	0–4	*19.68a	18.64a	18.79a	1.26a	1.29a	1.28a	5.34a	5.14a	4.94a	1.75a	1.92a	2.39b
	4–8	21.25a	17.51b	16.89b	1.45a	1.41a	1.34b	4.76a	4.60a	4.69a	1.17a	1.19a	1.75a
15-year acacia plantation	0–4	20.67a	16.71b	16.53b	1.13a	1.15a	1.39b	4.51a	4.50a	4.51a	1.87a	1.47a	0.81b
	4–8	22.47a	19.19b	15.61c	1.15a	1.28b	1.47c	4.44a	4.41a	4.40a	1.84a	1.47a	0.81b
7-year acacia plantation	0–4	15.49a	15.48a	16.22a	1.30a	1.37a	1.32a	4.85a	4.59a	4.72a	1.50a	1.44a	1.51a
	4–8	13.42a	14.80a	13.05a	1.39a	1.39a	1.38a	4.54a	4.51a	4.47a	1.10a	1.19a	1.35b
Sitapahar natural forest	0–4	9.94a	12.54b	13.95b	1.32a	1.36a	1.14b	5.60a	5.08b	5.34a	1.42a	1.79a	2.16b
	4–8	12.03a	13.82a	12.89a	1.35a	1.39a	1.32a	4.88a	4.90a	4.86a	1.28a	1.60a	1.98b

*Each value is the mean of three plots. Different letters indicate significant difference between mean values of each property at three different hill positions in each forest type

Organic matter

Concentrations of soil organic matter in all four forest types showed declining trend towards hill bottom from hilltop, except for 15-year disturbed acacia plantation (Table 1). Concentrations of the organic matter were similar or higher in 0–4 cm than 4–8 cm soil depth. Organic matter concentrations varied in the surface soil in the four vegetation types between 0.81% in 15-year acacia plantation and 2.39% in 18-year mixed plantation, which even higher than natural forest (1.79%). The findings on soil moisture, pH and organic matter concentration, supported the first hypothesis that plantations definitely influence soil properties and change in the properties is more affected by natural forest than plantation.

Litter thickness

Litter thickness in four forest types did not show any definite trend with age. In 7-year plantation, litter thickness was uniform on each hill position and variable in top, middle and bottom hill positions. In this plantation, litter thickness at top, middle and bottom were 0.66 cm, 1.30 cm and 0.86 cm, respectively. In 15-year plantation, litter thickness was almost similar and thin. In 18-year mixed plantation, litter thickness was uniform on top and variable in middle and bottom hill positions. In natural forest mean litter thickness was 1.99 cm and almost uniform over the whole forest. However, this thickness was much lower than Hubbard Brook Experimental Forest of USA, where Gosz et al. (1976) reported the thickness of 5.3 cm.

Accumulation of litter

In each vegetation type, accumulation of both fresh and partially decomposed litter with humus varied significantly ($p \leq 0.05$) on three hill positions (Table 2). This result did not support the second hypothesis that accumulation of organic matter at all the hill

positions would be similar. Accumulation of both the litter forms was highest on bottom slope, and significantly ($p \leq 0.05$) decreased towards hilltop in 7- and 18-year plantations and increased significantly ($p \leq 0.05$) in 15-year disturbed acacia plantation. Lower value on bottom hill position in the disturbed acacia plantation was associated with the removal of litter by surrounding fuel collectors for their daily needs due to easy access to lower part of the hill than steep hilltop, where access not frequent and easy. Bhuyian et al. (1995) reported that 494 persons daily extracted 1.08 t of fuel wood outside green fodder, bamboo, thatching material, timber and pole from 12 000 ha land of Chittagong University and from adjoining degraded forest areas either for own consumption or sale or both. In other three forest types, more accumulation of litter on bottom hill compared to hilltop was due to blown litter by wind and gravitational force from upper to lower place. Boerner and Kooser (1989) also reported similar effect of slope on litter movement, who found net down slope litter movement as large as vertical litter fall in most sites in un-glaciated Allegheny Plateau of Ohio, USA.

Table 2. Organic matter production (kg/ha) in different decomposition stages in four forest types of Chittagong region in Bangladesh

Forest type	Organic matter of fresh litter($kg \cdot ha^{-1}$)				Organic matter of partially decomposed litter with humus ($kg \cdot ha^{-1}$)				Organic matter in soil (z)	Total organic matter production (x + y + z)
	Top	Middle	Bottom	Mean (x)	Top	Middle	Bottom	Mean (y)		
18-year mixed plantation	*3120.0a (173.33)	5573.33b (309.63)	8226.67c (457.03)	5640.00 (30.48)	1346.67a (74.82)	2706.67b (150.37)	4173.33c (231.85)	2742.22 (14.82)	10122.00 (54.70)	18504.22 (1028)
15-year acacia plantation	2226.80a (148.45)	2200.00a (146.67)	1733.20b (115.54)	2053.33 (19.40)	1413.20a (94.21)	760.00b (50.67)	573.20b (38.21)	915.47 (8.64)	7618.00 (71.96)	10586.80 (705.79)
7-year acacia plantation	5666.67a (809.52)	7040.00b (1005.7)	7800.00b (1114.2)	6835.56 (38.23)	1840.00a (262.86)	2560.00b (365.70)	3640.00c (520.00)	2680.00 (14.99)	8364.60 (46.78)	17880.16 (2554.31)
Sitapahar natural forest	9346.67a	8160.00b	6813.33c	8106.67	2080.00a	2746.67b	3066.67b	2631.11	8714.60 (44.80)	19452.38
Mean	(377.10)	(487.33)	(562.26)	(32.45)	(143.96)	(188.99)	(263.35)	(13.50)	(54.56)	(1429.37)

*Each value is the mean of three plots. Figures in first brackets indicate annual accumulation rate in $kg \cdot ha^{-1} \cdot a^{-1}$. Figures in third brackets indicate % of total production. Different letters indicate significant difference between mean values of fresh litter or partially decomposed litter with humus at three different hill positions in each forest type

Accumulation rate of fresh litter and partially decomposed litter with humus was higher in 7-year acacia plantation than in 18-year mixed plantation indicating declining rate of accumulation with age (Table 2). Many reports also confirmed similar trend of accumulation rate with age (Evans 1981; Pritchett and Fisher 1987). In 7-year acacia plantation, accumulation rates of fresh litter and partially decomposed litter with humus on hilltop were 809.52 $kg \cdot ha^{-1} \cdot a^{-1}$ and 262.86 $kg \cdot ha^{-1} \cdot a^{-1}$, respectively, and their corresponding values in 18-year mixed plantation were 173.33 $kg \cdot ha^{-1} \cdot a^{-1}$ and 74.82 $kg \cdot ha^{-1} \cdot a^{-1}$. This result also did not support the hypothesis that accumulation of organic matter at different decomposition stages would increase with age. Although age of natural forest was unknown, height of some dominant trees was >33 m (Nath et al. 1997), suggesting the age of natural forest was several times higher than all the plantations. In natural forest maximum accumulation of fresh litter was on hilltop (9 346.67 $kg \cdot ha^{-1}$) and for partially decomposed litter with humus on hill bottom (3 066.67 $kg \cdot ha^{-1}$). In 7-, 15- and 18-year plantations, rates of total organic matter production consisting of fresh, partially and completely decomposed litter as well as incorporated organic matter in soil were 2 554.31, 705.79 and 1 028.01 $kg \cdot ha^{-1} \cdot a^{-1}$, respectively, and the corresponding contribution from fresh litter were 38.23, 19.40 and 30.48 $kg \cdot ha^{-1} \cdot a^{-1}$. These total rates were much less than even the lower limit of the range of litter fall varied from 2 000 to 12 000 $kg \cdot ha^{-1} \cdot year^{-1}$ reviewed by Pritchett and Fisher (1987) from a variety of species including conifers and hardwoods covering large geographical locations in both warm and cool temperate regions as well as in tropical rain forest. Accumulation rate of litter found here under the acacia plantation was lower than rates reported by Saharjo and Watanabe (2000) under *Acacia mangium*. They found 5 939 $kg \cdot ha^{-1} \cdot a^{-1}$ litter under *Acacia mangium* plantation in South Sumatra, Indonesia. Litter fall found here under the natural forest at Sitapahar was comparable to Liao et al. (2006), who reported litter fall ranging from 6 980 to 9 130 $kg \cdot ha^{-1} \cdot a^{-1}$, in coral reef tropical forest in southern Taiwan.

In Sitapahar natural forest at Kaptai, total production of organic matter was 19 452.38 $kg \cdot ha^{-1}$ of which, 8 106.67 $kg \cdot ha^{-1}$ for fresh litter, 2 631.11 $kg \cdot ha^{-1}$ for partially decomposed litter with humus and 8 714.60 $kg \cdot ha^{-1}$ for soil incorporated organic matter. These values were much lower than reported findings by Gosz et al. (1976) in Hubbard Brook Experimental Forest of USA. They found 3 600 kg litter layer and 43 160 kg fermented and humus (F+H) layer per hectare. From visits in other natural forests of this hilly region in Bangladesh, litter fall on forest floor was also observed very low due to rapid decomposition of litter within three months of falling under favorable tropical monsoon climatic conditions characterized by higher temperature and rainfall, accompanied by varied large number of soil flora and faunal communities as well as fragmentation of forest. In Chittagong University campus, plantations were not in a continuous form due to habitations and infrastructures of the university in valleys

and thus forests developed in rather fragmented forms on hills. Didham (1998) reported that litter decomposition rates increased significantly towards the edge of 100 ha forest fragments due to edge effects and decomposition rates were strongly affected by decreasing fragment area, and in contrast, there was no significant change in the rate of leaf-litter decomposition from the interior to the edge of the continuous tropical forest of Central Amazonia in Brazil. Total organic matter productions varied in the four forest types from 10 586.80 $kg \cdot ha^{-1}$ in 15-year disturbed acacia plantation to 19 452.38 $kg \cdot ha^{-1}$ in natural forest (Table 2). In four forest types, on an average fresh litter constituted 32.45%, partially decomposed litter with humus 13.50% and incorporated organic matter in soil 54.56% of the total organic matter production. Higher proportion of incorporation from fallen litter was associated with favorable climatic conditions in the region and fragmentation of forests in the university campus.

Hill forests in Bangladesh are under stresses from very dense population itself and migration of people from plain land due to shortage of agricultural land. People are settling now on the forest margins and depend on forest and its products for their livelihood through collection of litter and fuel wood, grazing animals and illicit felling. In effect, through the chain process starting from fuel wood collection to whole tree extraction by illicit felling, deforestation is going on at a faster rate in the country and atmospheric CO_2 increasing gradually. Under the situation, therefore, existing forest areas needs to manage cautiously to stop from further shrinking of the forest, to increase biomass including forest floor C sequestration with the aim to reuse the returned nutrients as litter in soil by plants through decomposition, and to gain many intangible benefits.

Conclusion

Litter accumulation at different decomposition stages varied significantly with hill positions and age of the plantations. Among different stages of organic matter, incorporated organic matter in soil was major portion as compared with all other forms together. Litter accumulation rates were many times lower in the forests of this hilly region of Bangladesh than either temperate region or tropical rain forests of the world.

References

Auchmoody LR. 1972. Nutrient properties of five West Virginia forest soil. Northeastern Exp. Station, USDA *For Serv Res* (Note No. NE-145): 4p.

Bhuyian MK, Haque SMS, Hossain MM, Ali M. 1995. Exploitation of forest produces from the Chittagong University Campus and its adjoining forest areas. *Chittagong University Studies*, *Part-II Science,* **19**(1): 1−5.

Boerner REJ, Kooser JG. 1989. Leaf litter redistribution among forest patches within an Allegheny Plateau Watershed. *Landscape Ecology*, **2**(2): 81−92.

Didham RK. 1998. Altered leaf litter decomposition rates in tropical forest fragments. *Oecologia,* **116**: 397−406.

Evans J. 1981. *Plantation Forestry in the Tropics*. Oxford: Oxford Science Publications, 471pp.

Fonte SJ, Schowalter TD. 2004. Decomposition of greenfall vs. senescent foliage in a tropical forest ecosystem in Puerto Rico. *Biotropica,* **36**(4): 474−482.

Gosz JR, Likens GE, Bormann FH. 1976. Organic matter and nutrient dynamics of the forest and forest floor in the hubbard brook forest. *Oecologia,* **22**: 305−320.

Haque SMS, Osman KT, Mia F. 1992. Growth of *Acacia auriculiformis, Dipterocarpus turbinatus* and *Pinus caribaea* at Chittagong University, *Chittagong University Studies, Part II Science,* **15**(1): 107−111.

Haque SMS. 1997. *Afforestation effect on former agricultural soils*. PhD. Dissertation, Univ. of Aberdeen, Scotland, UK, 335pp.

Hassan MM, Islam ATMN. 1984. The contribution of bamboo and some broad leaved species to the soil organic matter content. *Indian Journal of Forestry*, **7**(3): 217−220.

Jha MN, Gupta MK, Dimri BM. 1999. Soil organic matter status under different social forestry plantation. *Indian Forester*, **125**(9): 883−890.

Liao JH, Wang HH, Tsai CC, Hseu ZY. 2006. Litter production, decomposition and nutrient return of uplifted coral reef tropical forest. *Forest Ecology and Management*, **235**(1-3): 174−185.

Miah MM, Rahman MM, Haque SMS. 2001. Carbon assimilation in three-year old mixed plantations in Chittagong region of Bangladesh. *The Chittagong Univ J Sci,* **25**(1): 11−16.

Monson RK, Turnipspeed AA, Sparks JP, Harley PC, Scottdenton LE, Sparks K, Huxman TE. 2002. Carbon sequestration in a high-elevation, subalpine forest. *Global Change Biology,* **8**: 459−478.

Nath TK, Hossain MK, Alam MK. 1997. Studies on the structural composition of natural forest of Chittagong Hill Tracts (South) Forest Division based on diameter class distribution. *Chittagong University Studies,, Part II: Science*, **21**(1): 15−22.

Osman KT, Haque SMS, Mia F. 1992a. Above ground biomass and nutrient distribution in *Acacia auriculiformis, Dipterocarpus turbinatus* and *Pinus caribaea* plantations at Chittagong University Hills, *Indian J Forestry*, **15**(3): 193−197.

Osman KT, Islam MS, Haque SMS. 1992b. Performance of some fast growing trees in the University of Chittagong, Campus. *Indian Forester,* **118**(11): 858−859.

Osman KT, Haque SMS, Rahman MM. 1995. Effect of forest plantations on soil properties at Keochia Silvicultural Research Station, Chittagong. *Indian Forester*, **121**(12): 1108−1117.

Pandey U, Singh JS. 1984. Nutrient changes and release during decomposition of leaf litter in a Himalayan (India) Oak–conifer forest. *Can J Bot*, **62**(9): 1824−1831.

Post WM, Kown KC. 2000. Soil carbon sequestration and land use change: process and potential. *Global Change Biology*, **6**: 317−327.

Pritchett WL, Fisher RF. 1987. *Properties and Management of Forest Soils*. New York: John Wiley and Sons.

Saharjo BH, Watanabe H. 2000. Estimation of litter fall and seed production of *Acacia mangium* in a forest plantation in South Sumatra, Indonesia. *Forest Ecology and Management,* **130**(1-3): 265−268.

Schlesinger WH. 1997. *Biogeochemistry: An analysis of global change,* 2nd edition. California: Academic Press, San Diego.

SRDI 1974. *Detail soil survey in Chittagong University campus*, Soil Resources Development Institute, Bangladesh.

Terakunpisut J, Gajaseni N, Ruankawe, N. 2007. Carbon sequestration potential in aboveground biomass of Thong Pha Phum National Forest, Thailand. *Applied Ecology and Environmental Research,* **5**(2): 93−102.

Zheng Z, Shanmughavel P, Sha L, Cao M, Warren M. 2006. Litter decomposition and nutrient release in a tropical seasonal rain forest of Xishuangbanna, Southwest China. *Biotropica,* **38**(3): 342−347.